

What is claimed is:

1. A method of using a processor to analyze data signals representing tomography scan images of an organic object, the method comprising:
 - a) receiving data representing successive tomography scan images of said object;
 - b) performing calculations by imposing an inequality constraint to determine dynamic data values from said data, each of said dynamic data values representing a physical property of said object at a respective corresponding one of a plurality of voxels of said object at a respective corresponding time; and
 - c) producing a representation of said dynamic data values, representing said physical property at said voxels at said times.
2. A method as claimed in claim 1 wherein performing said calculations includes minimizing a figure of merit function subject to said inequality constraint.
3. A method as claimed in claim 2 wherein performing said calculations includes minimizing said figure of merit function subject to linear basis functions constrained by a linear inequality constraint selected from the following group wherein N represents the number of said respective times:

$$\text{a) } x_{i1} \geq x_{i2} \geq x_{i3} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0;$$

$$\text{b) } 0 \leq x_{i1} \leq x_{i2} \leq x_{i3} \dots \leq x_{i,N-1} \leq x_{iN};$$

$$\text{c) } 0 \leq x_{i1} \leq x_{i2} \dots \leq x_{i,P-1} \leq x_{i,P} \geq x_{i,P+1} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0;$$

$$\text{d) } 0 \leq x_{i1} \leq x_{i2} \dots \leq x_{i,P-v_i} \text{ and } x_{i,P+v_i} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0;$$

$$e) \quad 0 \geq x_{i1} - x_{i2} \geq x_{i2} - x_{i3} \geq \dots \geq x_{i,N-1} - x_{i,N} \quad \text{and}$$

$$x_{i1} \geq 0, \dots, x_{iN} \geq 0;$$

$$f) \quad 0 \leq x_{i1} - x_{i2} \leq x_{i2} - x_{i3} \leq \dots \leq x_{i,N-1} - x_{i,N} \quad \text{and}$$

$$x_{i1} \geq 0, \dots, x_{iN} \geq 0; \quad \text{and}$$

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$$g) \quad 0 \geq x_{i1} - x_{i2} \geq x_{i2} - x_{i3} \geq \dots \geq x_{i,q_i} - x_{i,q_i+1} \quad \text{and}$$

$$x_{i,q_i} - x_{i,q_i+1} \leq x_{i,q_i+1} - x_{i,q_i+2} \leq \dots \leq x_{i,N-1} - x_{iN}.$$

4. A method as claimed in claim 1 wherein receiving data includes receiving data representing successive images detected at a Single Photon Emission Computed Tomography (SPECT) imaging device.

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5. A computer-implemented method of producing a representation of a measurable property which varies in time and space, the method comprising:

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- a) receiving a plurality of sets of values representing measurements of said property across an object at respective measurement times, each set being associated with a respective measurement time; and

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- b) producing a plurality of sets of values representing said property at a plurality of locations throughout said object at said respective measurement times, by minimizing a figure of merit function relating said values representing said measurements with said values representing said property at said plurality of locations, with a shape constraint imposed on said values representing said property at said plurality of locations.

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6. The method claimed in claim 5, wherein minimizing said figure of merit function further comprises solving for numerical values describing said

property for each of said locations throughout said object, said numerical values being constrained by said shape constraint.

7. The method claimed in claim 5, wherein minimizing said figure of merit function further comprises solving for linear basis functions describing said property for each of said locations throughout said object, said linear basis functions being constrained by said shape constraint.

8. The method claimed in claim 5, wherein minimizing said figure of merit function further comprises minimizing a sum of squares of a difference between a product of a linear operator and said values representing said property, and said values representing said measurements.

9. The method claimed in claim 8, wherein minimizing said figure of merit further comprises solving the following equation:

a) Minimize $\left\{ \sum_{j,k} \sigma_{jk}^{-2} \left(\sum_i C_{ijk} x_i(t_k) - d_{jk} \right)^2 + R(x) \right\}$, wherein:

b) d_{jk} comprises said plurality of sets of values representing said measurements d_j of said property across an object at respective measurement times t_k ;

c) $x_i(t_k)$ comprises said plurality of sets of values representing said property x at a plurality of locations i throughout said object at said respective measurement times t_k ;

d) $x_i(t_k) = x_{ik}$ are numerical values subject to said shape constraint comprising a linear inequality constraint selected from the following set of constraints, wherein N represents the number of said measurement times:

i) $x_{i1} \geq x_{i2} \geq x_{i3} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0$;

ii) $0 \leq x_{i1} \leq x_{i2} \leq x_{i3} \dots \leq x_{i,N-1} \leq x_{iN}$;

$$\text{iii)} \quad 0 \leq x_{i1} \leq x_{i2} \leq \dots \leq x_{i, P-1} \leq x_{i, P} \geq x_{i, P+1} \leq \dots \leq x_{i, N-1} \geq x_{i, N} \geq 0$$

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$$\text{iv)} \quad 0 \leq x_{i1} \leq x_{i2} \leq \dots \leq x_{i, P-v_i} \text{ and}$$

$$x_{i, P+v_i} \leq \dots \leq x_{i, N-1} \geq x_{i, N} \geq 0;$$

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$$\text{v)} \quad 0 \geq x_{i1} - x_{i2} \geq x_{i2} - x_{i3} \geq \dots \geq x_{i, N-1} - x_{i, N} \text{ and}$$

$$x_{i1} \geq 0, \dots, x_{iN} \geq 0;$$

$$\text{vi)} \quad 0 \leq x_{i1} - x_{i2} \leq x_{i2} - x_{i3} \leq \dots \leq x_{i, N-1} - x_{i, N} \text{ and}$$

$$x_{i1} \geq 0, \dots, x_{iN} \geq 0; \text{ and}$$

$$\text{vii)} \quad 0 \geq x_{i1} - x_{i2} \geq x_{i2} - x_{i3} \geq \dots \geq x_{i, i_q} - x_{i, i_q+1} \text{ and}$$

$$x_{i, i_q} - x_{i, i_q+1} \leq x_{i, i_q+1} - x_{i, i_q+2} \leq \dots \leq x_{i, N-1} - x_{iN}$$

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$$\text{e)} \quad C_{ijk} \text{ and } \sigma_{jk}^2 \text{ are weighting factors; and}$$

$$\text{f)} \quad R(x) \text{ is a regularizing term.}$$

10. The method claimed in claim 5, wherein minimizing a figure of merit function includes executing a math program on said values representing said measurements, said shape constraint being pre-specified to said math program.

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11. The method claimed in claim 5, further comprising producing a graphical representation of said object, for controlling a display device.

12. The method claimed in claim 11, further comprising producing a time varying graphical representation of said object to represent a change of said property over time.

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13. The method claimed in claim 11, further comprising transmitting said graphical representation to a display device for displaying a representation of said property.

14. The method claimed in claim **13**, further comprising displaying said representation of said property.
15. The method claimed in claim **14**, further comprising producing successive images representing said property at successive instants in time, in response to said representation of said property.
16. The method claimed in claim **15**, further comprising producing said successive images to depict a three dimensional representation of said property in said object which varies according to changes in said property over time.
17. The method claimed in claim **5**, further comprising producing said sets of values representing measurements of said property across said object at respective measurement times.
18. The method claimed in claim **17**, wherein producing comprises measuring radioactivity across said object.
19. The method claimed in claim **18**, wherein measuring radioactivity includes operating a Single Photon Emission Computed Tomography (SPECT) imaging device.
20. A signal produced by the method of claim **5**, said signal representing said plurality of sets of values representing said property at a plurality of locations throughout said object.
21. An apparatus for producing a representation of a measurable property which varies in time and space, the apparatus comprising:
- a) a receiver for receiving a plurality of sets of values representing measurements of said property across said object at respective measurement times, each set being associated with a respective measurement time; and

b) a processor circuit in communication with said receiver, said processor circuit being programmed to produce a plurality of sets of values representing said property at a plurality of locations throughout said object at said respective measurement times, by minimizing a figure of merit function relating said values representing said measurements with said values representing said property at said plurality of locations, with a shape constraint imposed on said values representing said property at said plurality of locations.

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22. The apparatus claimed in claim 21, wherein said processor circuit is programmed to solve for linear basis functions describing said property for each of said locations throughout said object, said linear basis functions being constrained by said shape constraint.

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23. The apparatus claimed in claim 21, wherein said processor circuit is programmed to minimize a sum of squares of a difference between a product of a linear operator and said values representing said property, and said values representing measurements of said property.

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24. The apparatus claimed in claim 23, wherein said processor circuit is programmed to solve the following equation:

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a) Minimize $\left\{ \sum_{j,k} \sigma_{jk}^{-2} \left(\sum_i C_{ijk} x_i(t_k) - d_{jk} \right)^2 + R(x) \right\}$, wherein:

b) d_{jk} comprises said plurality of sets of values representing said measurements d_j of said property across an object at respective measurement times t_k ;

c) $x_i(t_k)$ comprises said plurality of sets of values representing said property x at a plurality of locations i throughout said object at said respective measurement times t_k ;

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d) $x_i(t_k) = x_{ik}$ are numerical values subject to said shape constraint comprising a linear inequality constraint selected from the following set of constraints, wherein N represents the number of said measurement times:

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i) $x_{i1} \geq x_{i2} \geq x_{i3} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0$;

ii) $0 \leq x_{i1} \leq x_{i2} \leq x_{i3} \dots \leq x_{i,N-1} \leq x_{iN}$;

iii) $0 \leq x_{i1} \leq x_{i2} \dots \leq x_{i,p_i-1} \leq x_{i,p_i} \geq x_{i,p_i+1} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0$;

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iv) $0 \leq x_{i1} \leq x_{i2} \dots \leq x_{i,p_i-v_i}$ and

$x_{i,p_i+v_i} \dots \geq x_{i,N-1} \geq x_{iN} \geq 0$;

v) $0 \geq x_{i1} - x_{i2} \geq x_{i2} - x_{i3} \geq \dots \geq x_{i,N-1} - x_{iN}$ and

$x_{i1} \geq 0, \dots, x_{iN} \geq 0$;

vi) $0 \leq x_{i1} - x_{i2} \leq x_{i2} - x_{i3} \leq \dots \leq x_{i,N-1} - x_{iN}$ and

$x_{i1} \geq 0, \dots, x_{iN} \geq 0$; and

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vii) $0 \geq x_{i1} - x_{i2} \geq x_{i2} - x_{i3} \geq \dots \geq x_{i,q_i} - x_{i,q_i+1}$ and

$x_{i,q_i} - x_{i,q_i+1} \leq x_{i,q_i+1} - x_{i,q_i+2} \leq \dots \leq x_{i,N-1} - x_{iN}$

e) C_{ijk} and σ_{jk}^2 are weighting factors; and

f) $R(x)$ is a regularizing term.

25. The apparatus claimed in claim 21, wherein said processor circuit is programmed to produce a graphical representation of said object, for controlling a display device.

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26. The apparatus claimed in claim 25, wherein said processor circuit is programmed to produce a time varying graphical representation of said object to represent a change of said property over time.
- 5 27. The apparatus claimed in claim 26, further comprising a transmitter for transmitting said graphical representation to a display device for displaying a representation of said property.
28. The apparatus as claimed in claim 21, further comprising a transmitter for transmitting said values representing said property to a display device for displaying a representation of said property.
- 10 29. The apparatus claimed in claim 28, further comprising a display for displaying said representation of said property.
30. The apparatus claimed in claim 29, wherein said processor circuit is programmed to produce successive images representing said property at successive instants in time, in response to said representation of said property.
- 15 31. The apparatus claimed in claim 30, wherein said processor circuit is programmed to produce said successive images to depict a three dimensional representation of said property in said object which varies according to changes in said property over time.
- 20 32. The apparatus claimed in claim 21, further comprising a device for producing said sets of values representing measurements of said property across said object at respective measurement times.
33. The apparatus claimed in claim 32, wherein said device comprises a radioactivity measurement device for measuring radioactivity across said object.
- 25 34. The apparatus claimed in claim 33, wherein said device includes a tomography scanner.

35. The apparatus as claimed in claim 33, wherein said radioactivity measurement device comprises a Single Photon Emission Computed Tomography (SPECT) imaging device.

5 36. An apparatus for producing a representation of a measurable property which varies in time and space, the apparatus comprising:

a) means for receiving a plurality of sets of values representing measurements of said property across said object at respective measurement times, each set being associated with a respective measurement time; and

10 b) means for producing a plurality of sets of values representing said property at a plurality of locations throughout said object at said respective measurement times, by minimizing a figure of merit function relating said values representing measurements with said values representing said property at a plurality of locations, with a shape constraint imposed on said values representing said property at a plurality of locations.

15 37. A computer readable medium for providing computer readable instructions for directing a programmable device to implement a method of producing a representation of a measurable property which varies in time and space by:

a) receiving a plurality of sets of values representing measurements of said property across said object at respective measurement times, each set being associated with a respective measurement time; and

20 25 b) producing a plurality of sets of values representing said property at a plurality of locations throughout said object at said respective measurement times, by minimizing a figure of merit function relating said values representing measurements with

said values representing said property at a plurality of locations, with a shape constraint imposed on said values representing said property at a plurality of locations.

- 5 **38.** A computer data signal embodied in a carrier wave for directing a programmable device to implement a method of producing a representation of a measurable property which varies in time and space, said data signal comprising:

10 a) a code segment for directing a programmable device to receive a plurality of sets of values representing measurements of said property across said object at respective measurement times, each set being associated with a respective measurement time; and

15 b) a code segment for directing a programmable device to produce a plurality of sets of values representing said property at a plurality of locations throughout said object at said respective measurement times, by minimizing a figure of merit function relating said values representing measurements with said values representing said property at a plurality of locations, with a shape constraint imposed on said values representing said property at a plurality of locations.

- 39.** A method of producing an image representing changes of radioactivity in an object, the method comprising;

25 a) receiving a plurality of sets of values representing tomography scan images across said object at respective measurement times, each set being associated with a respective measurement time;

b) producing a plurality of sets of values representing radioactivity at a plurality of locations throughout said object at said

respective measurement times, by minimizing a figure of merit function relating said values representing said tomography scan images with said values representing radioactivity, with a shape constraint imposed on said values representing radioactivity; and

- c) producing a visual representation of said object in response to said plurality of sets of values representing radioactivity, said visual representation including a representation of radioactivity over time.

40. An apparatus for producing an image representing changes of radioactivity in an object, the apparatus comprising;

- a) a receiver for receiving a plurality of sets of values representing tomography scan images across said object at respective measurement times, each set being associated with a respective measurement time;
- b) a processor circuit programmed to produce a plurality of sets of values representing radioactivity at a plurality of locations throughout said object at said respective measurement times, by minimizing a figure of merit function relating said values representing said tomography scan images with said values representing radioactivity, with a shape constraint imposed on said values representing radioactivity; and programmed to produce a time varying graphical representation of said object in response to said plurality of sets of values representing radioactivity; and
- c) a display responsive to said graphical representation for producing a visual representation of said object in response to said graphical representation.